Diagnosing subseasonal predictability of tropical atmospheric anomalies

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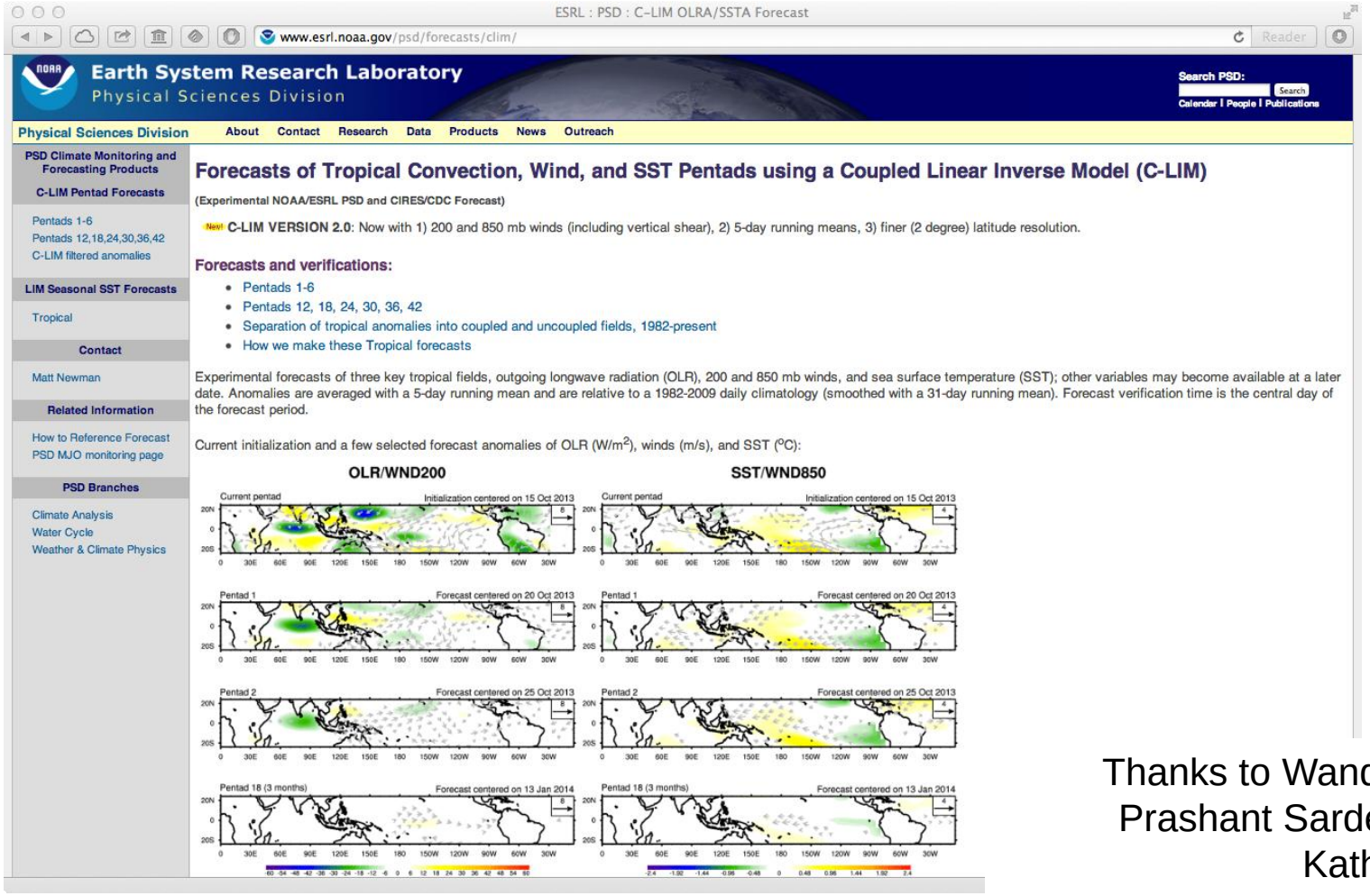


Thanks to Wanqiu Wang, Prashant Sardeshmukh, Kathy Pegion

"Multivariate Red Noise" null hypothesis

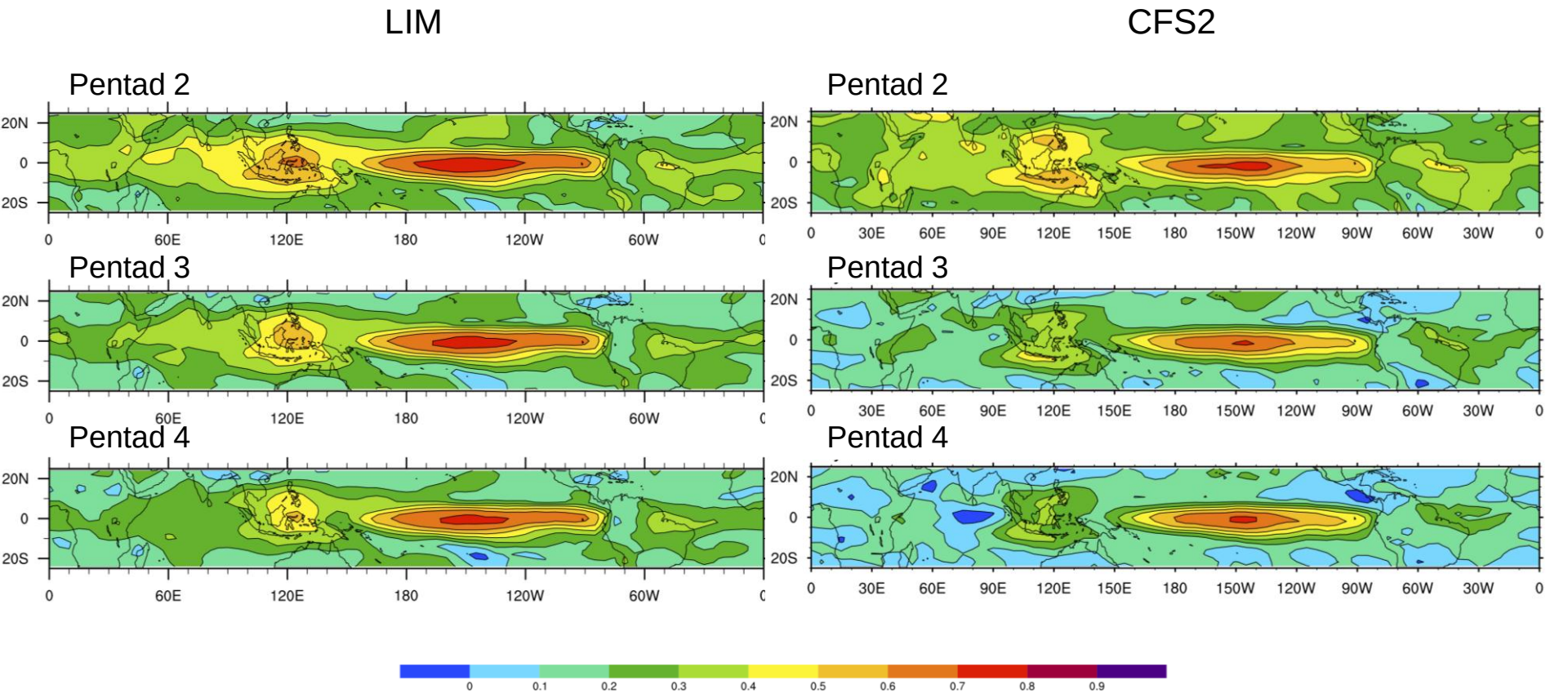
$$d\mathbf{x}/dt = \mathbf{L}\mathbf{x} + \mathbf{F}_s$$

$\mathbf{x}(t)$ is a series of maps, $\mathbf{L}$ is stable, and $\mathbf{F}_s$ is white noise (maps)

- Determine **L** and $\mathbf{F}_s$ using "Linear Inverse Model" (LIM)
  - ***x*** is ***SST/OLR/200 and 850 mb wind*** 5-day running mean anomalies in Tropics, 1982-2009 (similar to Newman, Sardeshmukh, and Penland 2009, *J. Climate*)
  - prefiltered in reduced EOF space
  - LIM determined from specified lag τ_o=5 (e.g., the data averaging interval) as in AR1 model, using τ_o- and zero-lag covariance of **x**
  - Test the LIM over much longer time intervals: observed spatio-temporal lag-covariance statistics very well reproduced
  - Hindcasts determined from cross-validation (10% data withheld to recompute **L**)

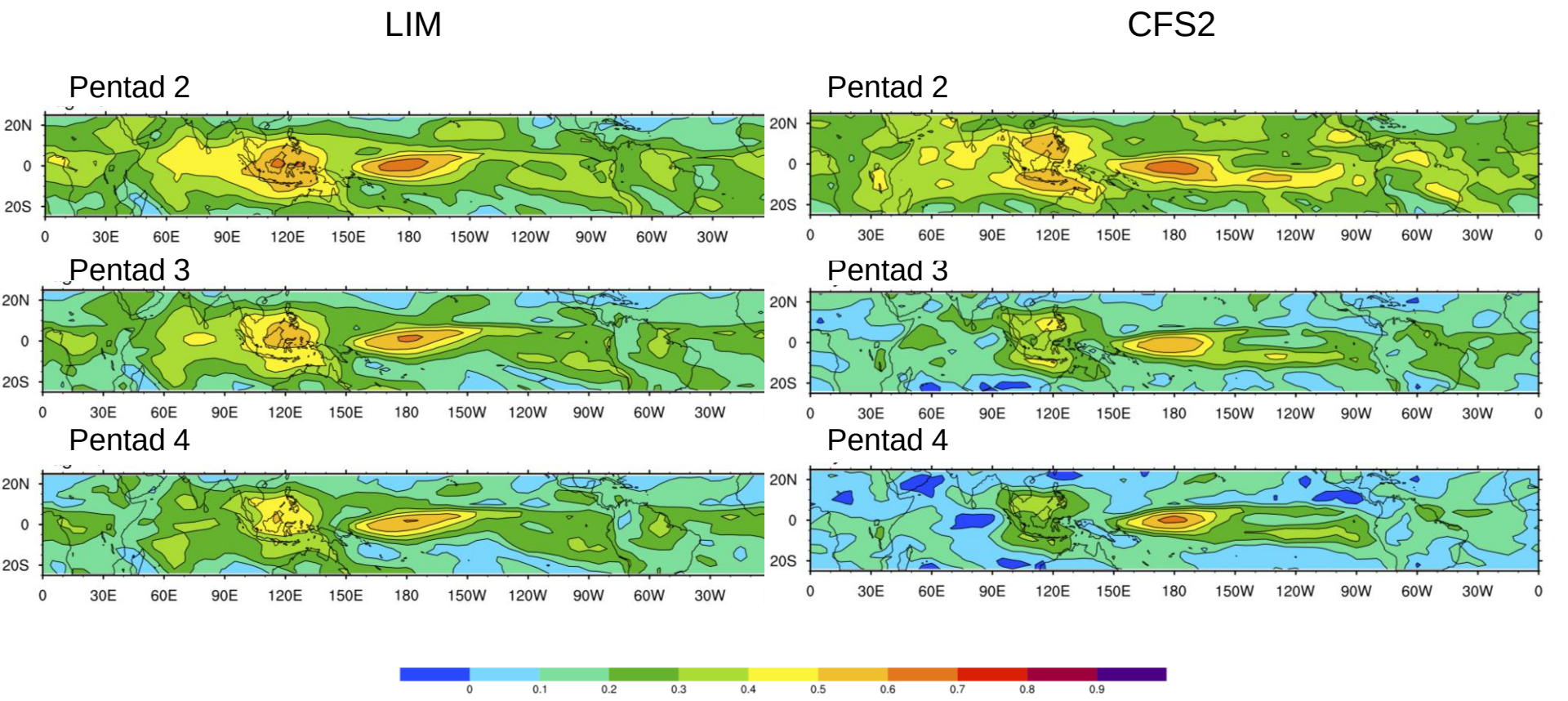
LIM has skill comparable to CFS2

OLR forecast skill, 1982-2009



LIM has skill comparable to CFS2

OLR forecast skill, 1999-2009



Using LIM to estimate predictability

$$\mathbf{d\,x/dt} = \mathbf{L\,x} + \mathbf{F_s}$$

$\mathbf{L}$ = constant, $\mathbf{F_s}$ = additive (state-independent) noise.

$$\mathbf{x}(t+\tau) = \exp(\mathbf{L}\tau)\,\mathbf{x}(t) + \varepsilon \equiv \mathbf{G}(\tau)\,\mathbf{x}(t) + \varepsilon$$

"signal" / "noise"

Expected forecast error covariance

(assuming no initial error) :

$$\mathbf{E}(\tau) = \langle \varepsilon\,\varepsilon^{T} \rangle = \mathbf{C}(0) - \mathbf{G}\,\mathbf{C}(0)\,\mathbf{G}^{T}$$

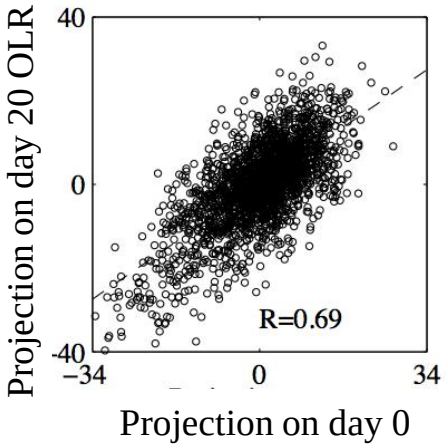
Expected forecast anomaly correlation

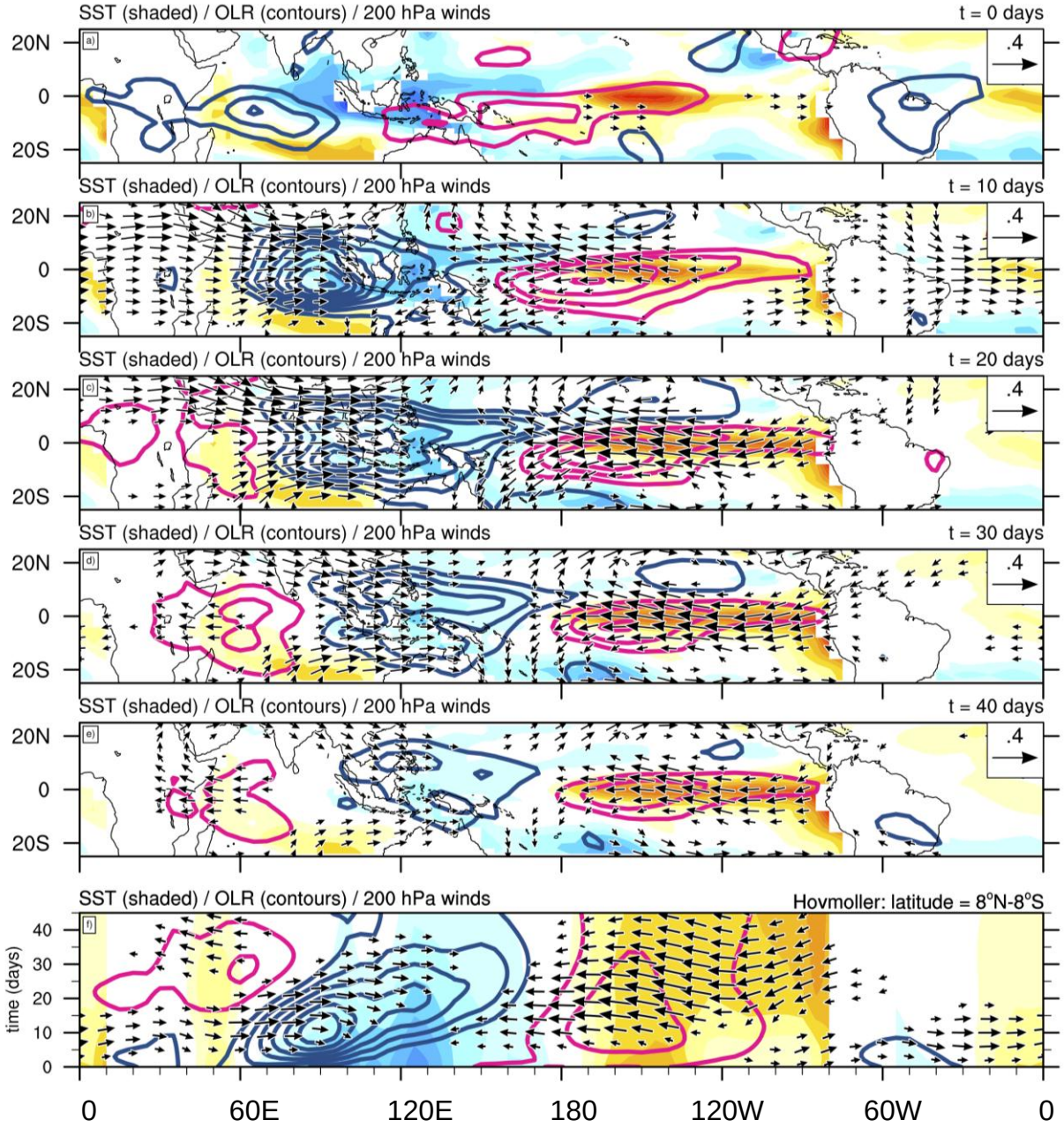
$$\rho_{\infty} = \frac{s}{\sqrt{1+s^2}}, \text{ where } s^2 = \frac{[\mathbf{G}\,\mathbf{C}(0)\,\mathbf{G}^{T}]_{ii}}{[\mathbf{E}(\tau)]_{ii}}$$

Larger signal related to leading singular vector of G(τ)

“Optimal” structure leading to greatest tropical OLR anomaly growth over 20 days

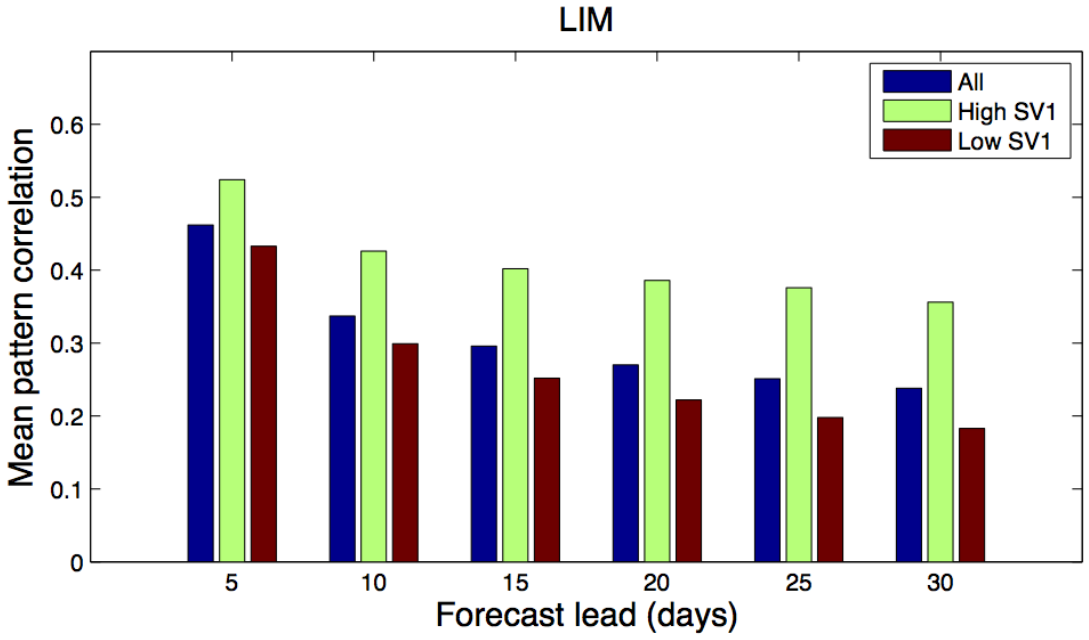
Shading: SST
Contours: OLR
Vectors: 200 mb winds

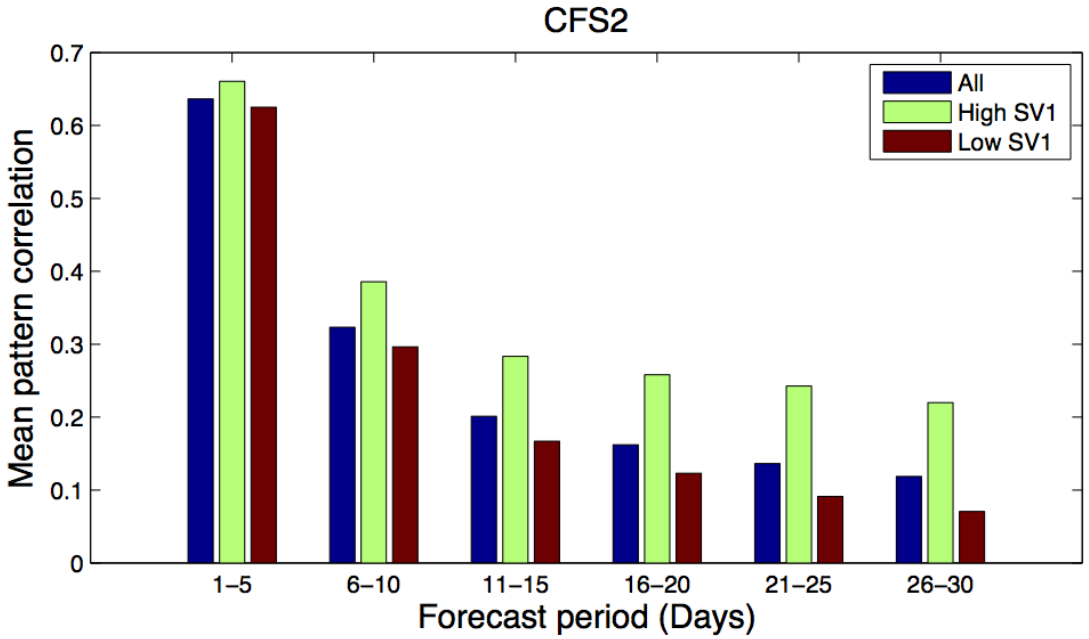




Using LIM to identify relatively more skillful forecast cases *a priori* from forecast signal-to-noise ratio

Pattern correlation of tropical IndoPacific OLR hindcasts, 1982-2009, stratified by whether initial conditions **do** or **do not** strongly project on initial growth structure (SV1)





Two distinct eigenmode spaces in L

"coupled"

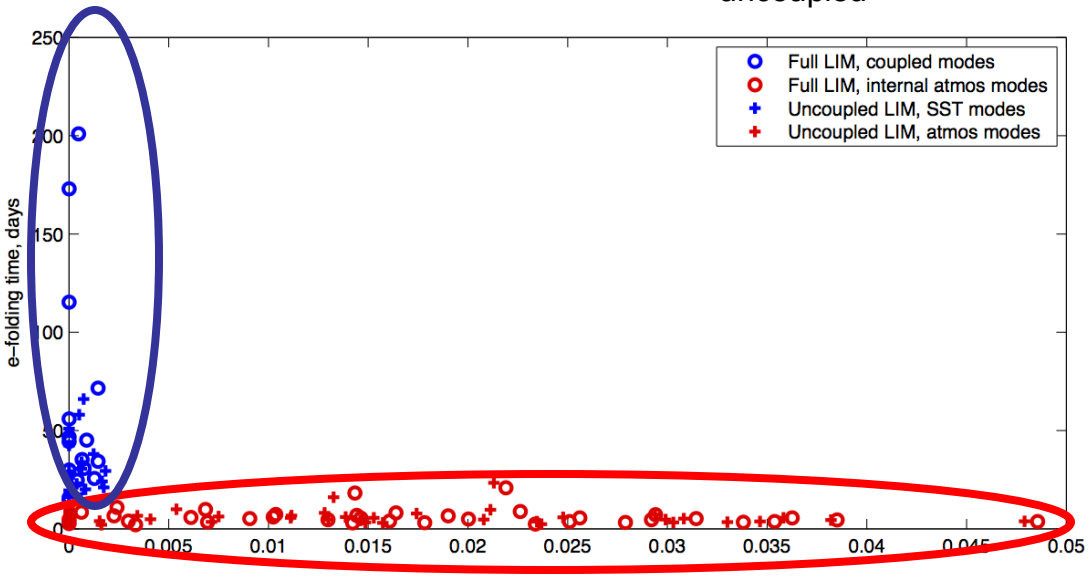
Longer eft, low frequency modes strongly modified by coupling within **L**

"internal atmospheric"

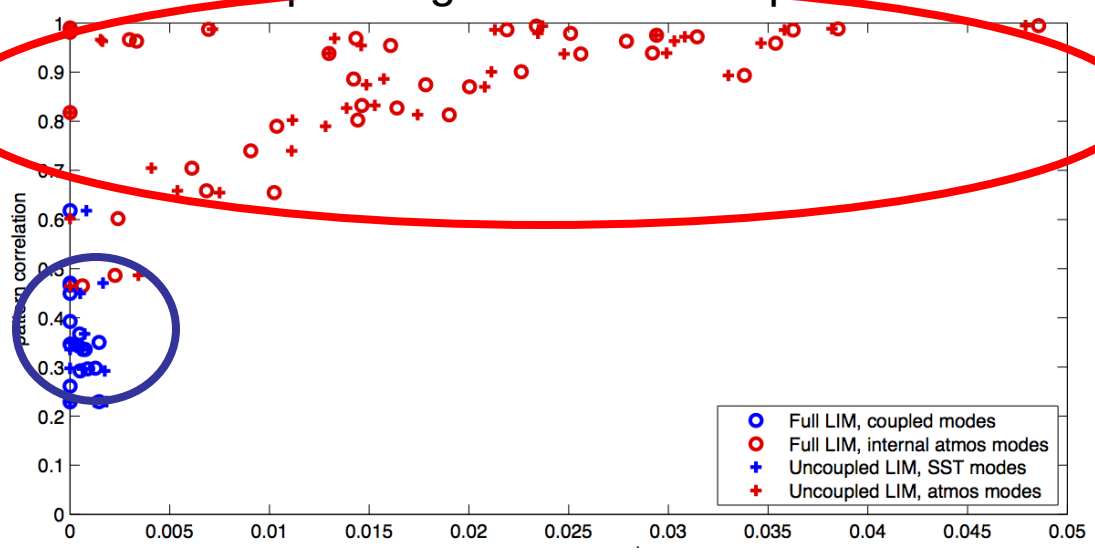
Short eft, high frequency modes only slightly modified by coupling within **L**

(Newman et al. 2009)

Eigenvalues of **L** and $\mathbf{L}_{uncoupled}$



Maximum pattern correlation between corresponding full and uncoupled modes



Frequency (days^{-1})

Project tropical state vector **x** into "coupled" and "internal" subspaces of full operator **L**

Define

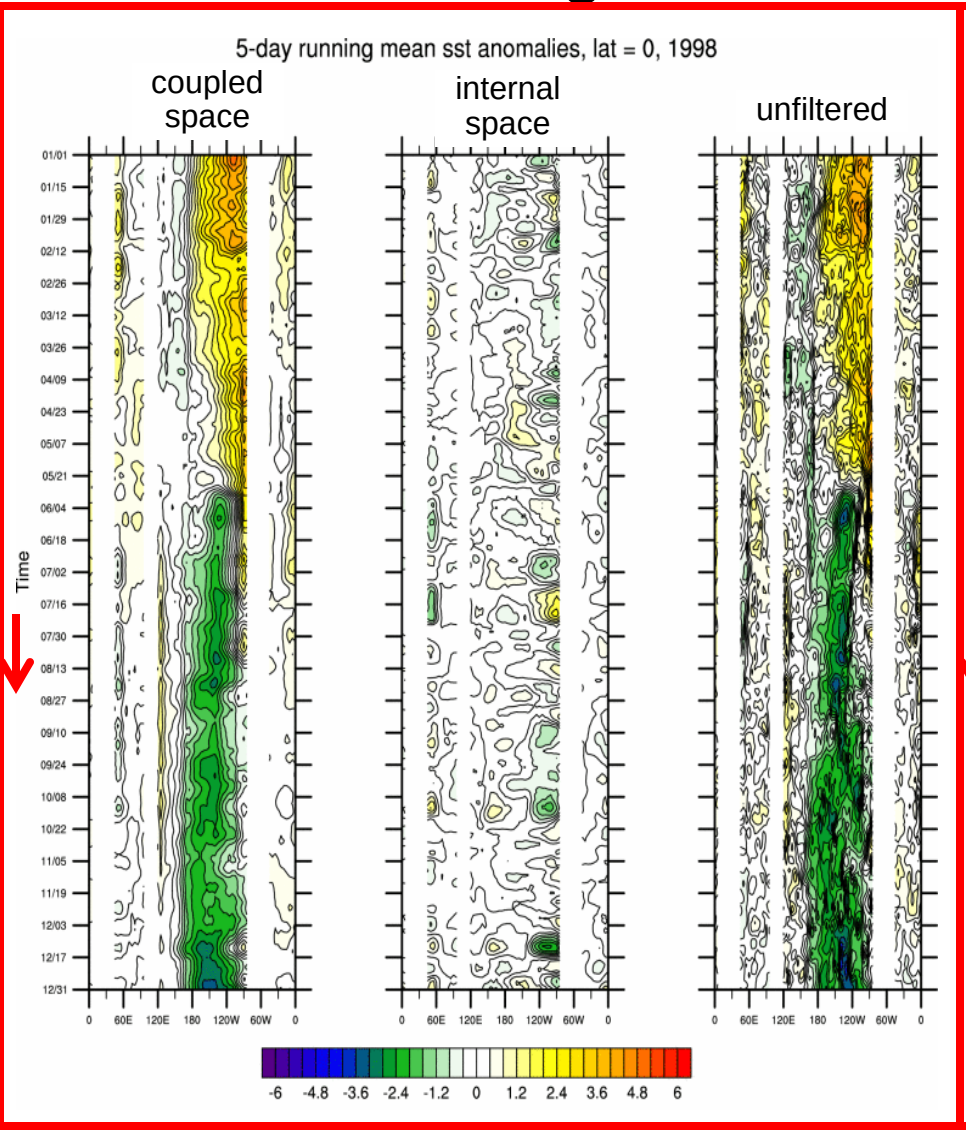
$$\mathbf{x} = \mathbf{x}^{\text{coup}} + \mathbf{x}^{\text{int}}$$

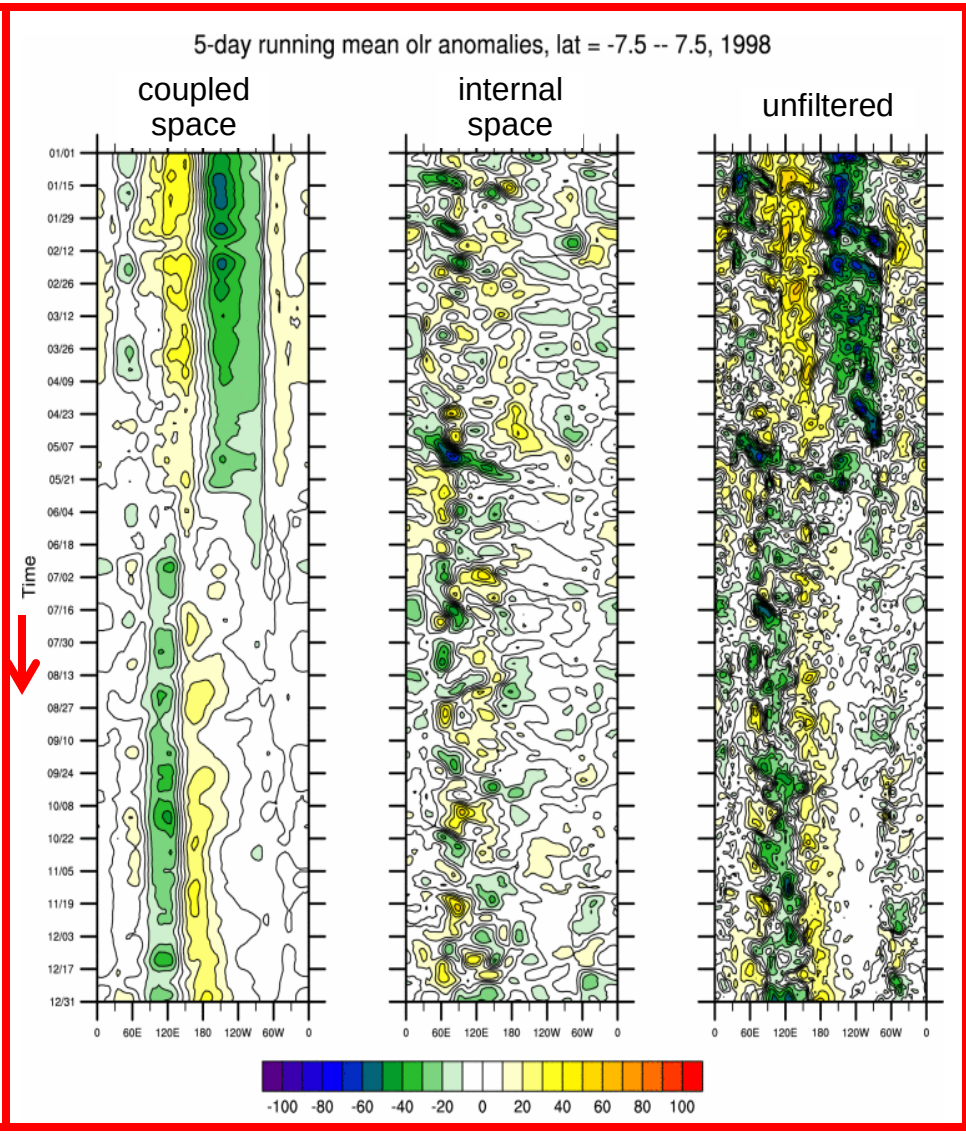
where

$$\mathbf{x}^{\text{coup}} = \sum_j \mathbf{u}_j^{\text{coup}} \alpha_j^{\text{coup}}(t) \qquad \mathbf{x}^{\text{int}} = \sum_j \mathbf{u}_j^{\text{int}} \alpha_j^{\text{int}}(t)$$

Note: $\mathbf{x}^{\text{coup}}$ and $\mathbf{x}^{\text{int}}$ need not be orthogonal

Using the LIM to “filter” the data





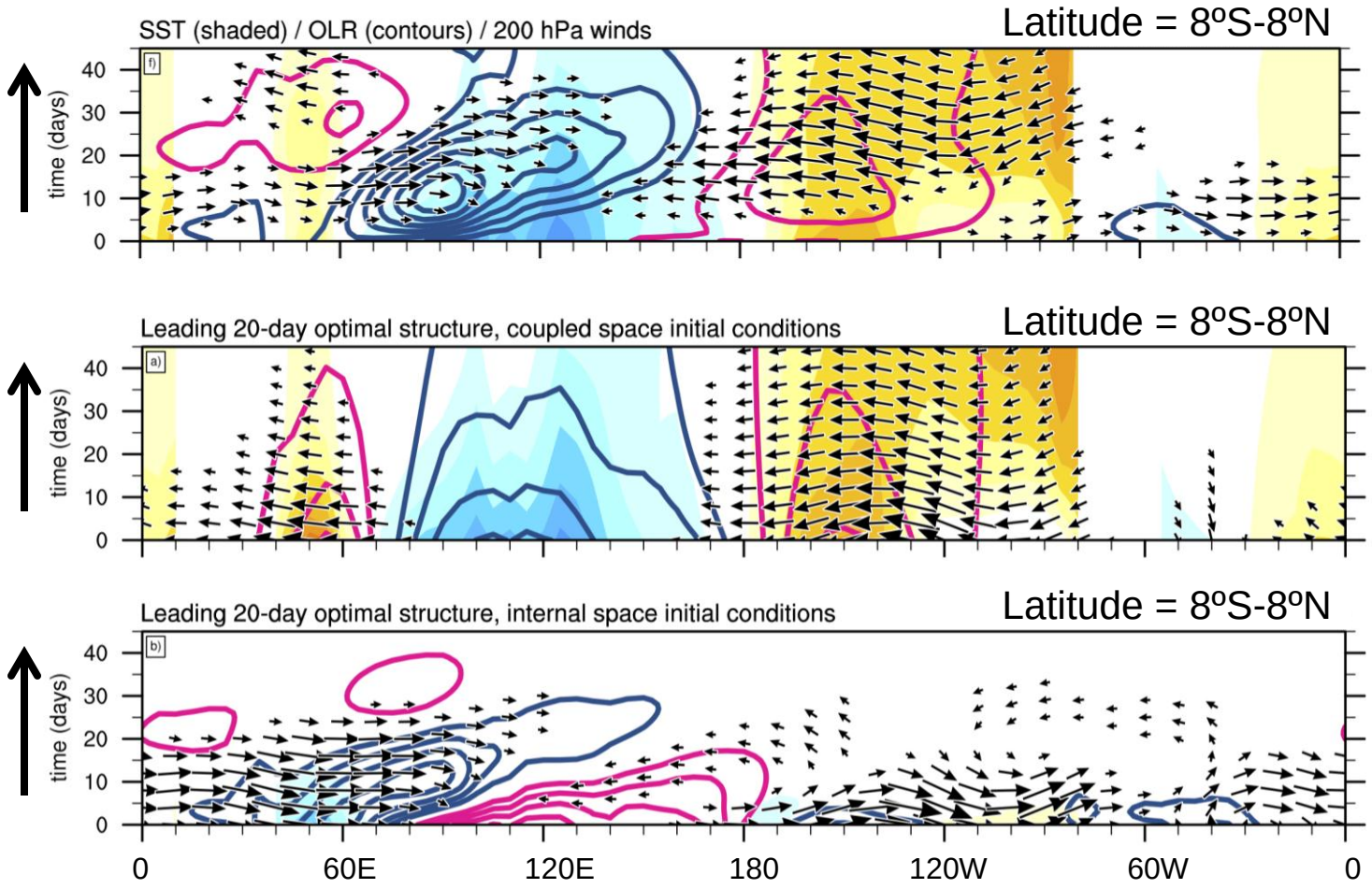
1. **no temporal filter is applied**
2. **interannual variability defined dynamically**

Optimal structure for 20-day OLR anomaly growth, decomposed into coupled and internal spaces

total

= coupled

+ internal



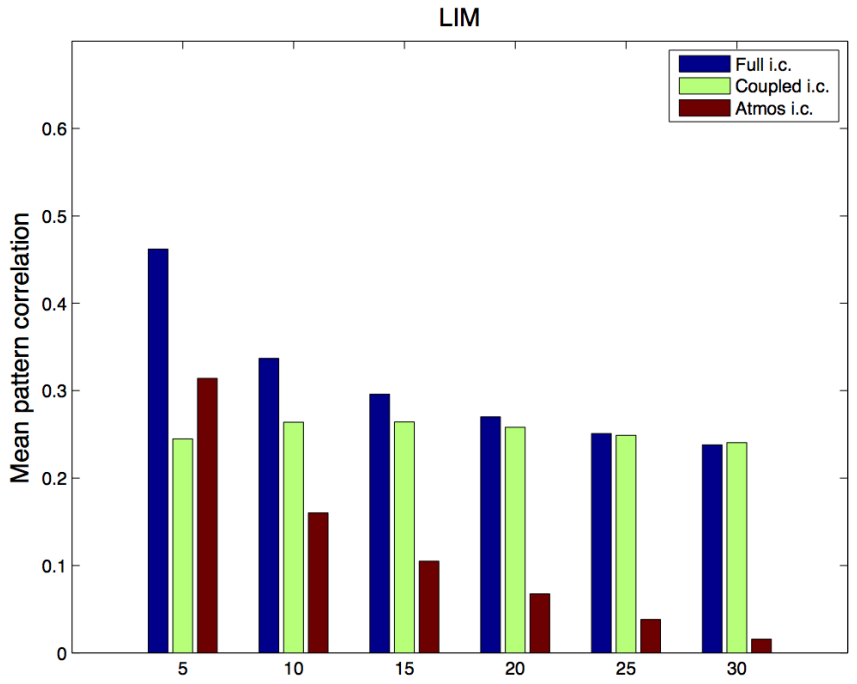
Maximum growth: coupled and internal spaces evolve from destructive to constructive interference

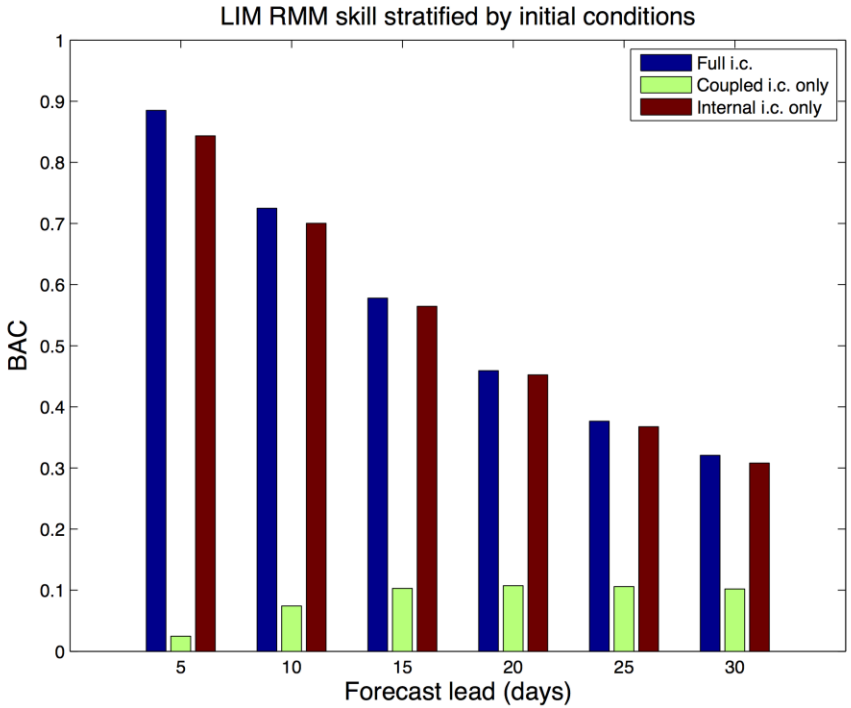
Shading: SST
Contours: OLR
Vectors: 200 mb winds

Most LIM skill due to coupled space initial conditions for leads > 15 days

Pattern correlation of tropical IndoPacific OLR LIM hindcasts, 1982-2009, where forecast initial conditions are either:

Full
Coupled space only
Internal space only





Conclusions

- LIM useful for diagnosis of predictability, ***because*** its forecast skill is comparable with coupled GCMs and it reproduces observed spatio-temporal statistics
- In Tropics, two nonorthogonal linear dynamical systems:
  - Slow (~interannual) coupled space **more predictable even for relatively "short" leads**
  - Fast (~intraseasonal) internal atmosphere space **less predictable, although MJO in this space**
  - Projecting data onto coupled space acts as an effective "filter"; MJO indices may convolve dynamics
- Subseasonal forecast skill may itself be *predicted* based on LIM signal-to-noise
  - In LIM, there is no "spread/skill" relationship, but note this need not be a constraint for all linearly predictable systems
  - Plan to institute "forecasts of forecast skill" in LIM forecast web page http://www.esrl.noaa.gov/psd/forecasts/clim/

Bivariate correlation (CORR) and RMSE for PC1 and PC2

i. Definition of Intraseasonal anomaly

$F' = F - F_c - F_L$

F : Total field

F_c : Daily climatology

F_L: Previous 90-day average of $F - F_c$

ii. Target period for calculating CORR and RMSE

9May1999 - 31Dec2009

iii. Calculation of PCs

- Base EOFs were computed with combined fields NOAA OLR and CFSR U200/ U850 (15S-15N average and 20-90-day filtered) (Wang et al. 2013.)
- F' of pentad average from CFSv2, CLIM, and observations (NOAA OLR, and R1 U200/U850) are projected onto the base EOFs
- The resulting PCs are normalized by the standard deviation of the PCs of the observation